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EP 0 325 456 B1

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Description

This invention relates to a diathermy unit.

Conventional mains-powered diathermy units commonly apply radio frequency (r.f.) energy to the tissue to be treated at a power level determined by a power control circuit for controlling the amplitude of the r.f. signal generated by an r.f. oscillator. However, in practice, human tissue presents a widely variable electrical load, resulting in poor impedance matching of the r.f. output of the unit to the load in most circumstances so that, of the power generated, often only 20 per cent is dissipated in the load. Bipolar diathermy typically requires an applied r.f. power level of 10 watts, but in view of the inefficiency resulting from poor matching, a unit capable of generating much higher power levels than 10 watts is necessary and for this reason a battery-powered diathermy unit requires a large battery. This is especially inconvenient if the unit is designed for hand-held use.

GB-A-1419660 describes a device for the therapeutic treatment of cells or tissue by the very low power application of an oscillating current with a sawtooth waveform to the body of a patient using a two transistor oscillator. The transistors of the oscillator are repeatedly driven to saturation by the regenerative action of a transformer feedback arrangement, the repetition rate of the output waveform depending on a number of factors including the power supply voltage, the external load, and resistance of oscillator circuit components.

In "Electrosurgery in Dentistry" by Maurice J. Oringer published by W.B. Saunders Company of Philadelphia, U.S.A. in 1962, there is disclosed in Figure 15 on page 22 a valve-based multiple circuit diathermy unit having a self-oscillating triode output stage coupled to a plurality of output terminals via an auto-transformer.

In order to improve power efficiency in the field of diathermy generally, the present invention provides a diathermy unit comprising oscillator means for generating an oscillatory radio frequency output signal, the oscillator means having at least one diathermy output terminal for electrical connection to an electrical load in the form of living tissue, the oscillator means further having means for causing the radio frequency of the oscillating output signal to vary automatically in response to the resistance of the living tissue load while the unit is in use, and including components for forming a resonant output circuit, the said components including a step-up transformer and, coupled in series between the said transformer and the at least one output terminal, a capacitor which causes the resonant frequency of the resonant output circuit to vary with the said load resistance. Preferably the unit is characterised by a self-tuning oscillator, the said components being arranged such that the variable resonant frequency resonant circuit comprises, when the unit is coupled to the load, the combination of the said components and the load, and such that the resonant circuit determines the operating frequency of the oscillator.

Such a resonant circuit may comprise the parallel combination of a further capacitor and an inductance, which combination is coupled in series with the series-coupled capacitor across a pair of output terminals of the unit. Preferably, a decrease in load resistance results in a decreased signal frequency. Typically the values of the resonant circuit are chosen to yield output frequencies differing by a factor of the square root of 2 between zero and infinite load resistances. Thus, with an infinite load resistance, the output frequency may be 500 kHz whereas at zero load impedance the frequency may be 353 kHz.

The inductance of the resonant circuit may constitute or form part of the step-up transformer, which may be an auto-transformer coupled between, for example, the supply and the output terminal of an amplifying device.

Preferably, self-oscillation is achieved by feeding a proportion of the energy produced in the resonant circuit back to the input of the amplifying device, which may be a metal oxide semiconductor field effect transistor (MOSFET). Devices of this type can be obtained with sufficient power handling capability for the required output power of the unit, and have a high input impedance coupled with a sufficiently fast switching speed respectively to minimise the effect of the feedback circuit on the Q of the resonant circuit and to allow operation at frequencies in the order of 500 kHz.

By allowing the frequency to vary with the load resistance, the energy loss in the output circuitry of the unit can be reduced over a wide range of load values compared with conventional diathermy units, with consequent benefits in efficiency and increased practicability of a hand-held battery-powered unit.

Control of the average power delivered to the load may be brought about by pulse width modulation of the oscillator. Known diathermy units have used pulse width modulation to adjust measured output power, but the actual power dissipated in the load varies depending on the load resistance for any given mark-to space ratio.

The prefered diathermy unit includes means for controlling the level of its output in response to a feedback signal, preferably a signal representative of the current drawn by the output stage. This allows the power to be adjusted in response to changes in load resistance. In particular, the feedback signal may be made representative of estimated power values by multiplication of a signal

representative of the current drawn by the output stage and a signal representative of the supply voltage, allowing compensation for changes in the supply voltage which will occur if that voltage is unregulated, especially if the unit is battery-powered. In this connection, it will be understood that supply voltage regulation may be undesirable as it may involve significant power loss.

The applicants have found that one advantageous technique for obtaining a feedback signal representative of the actual output power of the unit is to monitor the voltage across a low resistance shunt in the supply to the output stage as a measure of the output stage current consumption and to apply this voltage, or one derived from it, to an input of an amplifier, the gain of which is variable in response to the level of a voltage, such as the supply voltage, governing the output power. The feedback signal obtained from the amplifier output is thus a function of the product of the current and, for example, the supply voltage.

An advantageous variable gain arrangement comprises an amplifier the gain of which is governed by the ratio of a feedback resistance and a series input resistance, one of these resistances being dynamically variable in response to the supply voltage level. Such variation may be achieved using a field effect transistor (FET) as one of the resistances, biased such that the source-to-drain resistance is substantially linearly related to the gate voltage. This near linear relationship may be achieved by biasing the FET so that the gate/channel junction is forwardly biased over at least the majority of the operating range of the gate voltage, for instance by using a depletion mode FET in the enhancement region of its characteristic. In such circumstances the gate is no longer voltage controlled, but current controlled. It has been found that this biasing technique produces a response characteristic of sufficient linearity while minimising offset inaccuracies when driving a differential gain-controlled amplifier.

Having thereby obtained a voltage representative of the output power, this voltage may be used to control pulse width modulation of the r.f. oscillator of the unit so as to complete a feedback loop for regulating power.

The invention is primarily applicable to a battery-powered bipolar diathermy unit but may also be used in mains-powered units, including unipolar units to improve their efficiency and power output characteristics. In a mains-powered unit, isolation of the output terminals of the unit may be provided by including a transformer with isolated windings in the resonant circuit.

The invention will now be described by way of example with reference to the drawings in which:-

Figure 1 is a simplified circuit diagram of an r.f. oscillator of a diathermy unit in accordance with the invention;

Figure 2 is a block diagram of a diathermy unit in accordance with the invention;

Figure 3 is a circuit diagram of a preferred diathermy unit;

Figure 4 is a graph illustrating the characteristics of an analogue multiplier arrangement; and

Figure 5 is a graph similar to that of Figure 4 illustrating the characteristics of a modified analogue multiplier arrangement.

Referring to Figure 1 of the drawings, a radio frequency oscillator suitable as a power oscillator for a diathermy unit has an amplifying device constituted by a power MOSFET 10 connectible to a load 12 in the form of human tissue via a step-up auto transformer 14 forming part of a resonant circuit 16. A d.c. supply line is coupled to the drain of the amplifying device via the primary winding 14A of the transformer 14, and the source is shown here connected to ground. The resonant circuit comprises the parallel combination of the series connected primary and secondary windings 14A and 14B of the transformer and a first capacitor 18, and a second capacitor 20 coupled in series with the parallel combination across a pair of output terminals 22 of the unit. Self-oscillation of the oscillator occurs due to positive feedback through a feedback capacitor 24 coupling one end of the parallel combination to the gate 26 of the device 10. In the preferred embodiment of the invention the gate 26 also acts as a control electrode for switching the oscillator on and off via terminal 28.

It will be appreciated that the resonant frequency of the resonant circuit 16 is dependent not only on the inductance value of the transformer 14 and its parallel capacitor 18, but also on the values of the second capacitor 20 and the load resistance. As a result, the oscillation frequency is governed by the load resistance which can vary widely depending on a number of factors related to the nature of the patient's tissue and the connection to it. Thus by making the oscillator the output stage of a diathermy unit, and allowing it to "self-tune" in response to the load, the unit may be matched to the load over a comparatively wide range of load resistances. Typically the capacitors have values within an order of magnitude of each other, i.e. the ratio of the values is less than 10 to 1, and in the present example are each 4.7 nanofarads.

By way of explanation, the Q (quality factor) of a resonant circuit is inversely proportional to the energy loss of that circuit. Energy losses within the inductance formed by the transformer 14 and the capacitor 18 are minimal in comparison to the dissipation in the load 12. When the resistance of the load approaches infinity, the applied voltage is

proportional to Q x V_s (V_s being the supply voltage) so that as the load resistance increases both the Q and the applied voltage become greater. Conversely, when the load resistance approaches zero, the current in the resonant circuit is relatively high and is proportional to Q x I_s where I_s is the supply current. Reducing the load resistance in these circumstances minimises the energy loss and consequently both the Q and the applied current are increased. This relationship holds provided the oscillator operates at the prevailing resonant frequency.

Use of a power MOSFET (such as type no. IRFZ 20) allows a power output of 10 Watts to be achieved while requiring only a small feedback current due to the high impedance of the gate of the device.

The ratio of the inductances of the primary and the secondary is dependent on the power required, the supply voltage (V+) and the matched load resistance, which is the resistance at which Q approaches 1. The secondary voltage is dependent on Q, thus the feedback energy to the gate of the amplifying device 10 will also change with load resistance.

The preferred embodiment of the invention is a diathermy unit which uses the above described power oscillator as the source of r.f. energy and as the output stage of the unit, as shown in Figure 2, where the oscillator is indicated by the reference numeral 30. To control the overall power output of the unit, the oscillator 30 is pulse-width modulated via the oscillator control input 28, the mark-to space ratio of the pulses applied to the control input being governed by a feedback control loop as shown. The loop is characterised by the generation of a signal representing an estimate of the actual power applied to the load via the terminals 22. In this embodiment, the estimate is based upon the assumption that the power output is approximately proportional to the product of the d.c. current drain of the oscillator 30 and the supply voltage level. This technique has the advantage that the mark-to-space ratio of the oscillator output can be varied in response to changes in load impedance as well as supply voltage level, allowing a selected power level to be maintained and yielding an improvement in performance into differing loads.

The supply voltage level is easily monitored. The current drain is measured by monitoring the voltage drop across a shunt resistance 32 connected in the oscillator supply. The unit has an analogue multiplier 34 for generating the required signal representative of the product of these two quantities, the product being formed preferably by feeding the signal from the shunt to an input of an amplifier the gain of which is variable in proportion to the supply voltage level, as will be described below.

Having derived a signal representative of the output power, this signal is filtered by a low-pass filter 36 and then compared with a reference voltage V_{REF} in a comparator 38. Feeding the "power error" switching signal obtained at the output of the comparator 38 to the control terminal 28 of the oscillator 30 has the effect of pulse modulating the oscillator, the frequency of modulation being dependent on time constants and switching threshold levels in the feedback loop. Power adjustment may be performed by varying the reference voltage V_{REF}, preferably in a series of steps. At the maximum power setting the arrangement of the circuitry is such that the mark-to-space ratio of the oscillator control signal is equal to or approaching 1 when the supply voltage is at a minimum operating level and the load impedance is at the extremes of the allowed range. At all other times the mark-to-space ratio is less.

The process of measuring the output power and controlling the oscillator will now be described in more detail with reference to the circuit diagram of Figure 3 and the graph of Figure 4.

Referring to Figure 3, the voltage from the current sensing shunt resistance 32, here a resistor of 20 milliohms, is fed to the non-inverting input of an operational amplifier 40, the gain of which is determined by the ratio of the feedback resistance 42 and the series input resistance of a field-effect transistor (FET) 44. In order for the gain of the amplifier 40 to the varied linearly with the supply voltage level, the gate of the FET 44 is coupled to a potential divider 46 connected across the voltage supply so as to bias the FET which is a depletion type into the enhancement region, i.e. with the gate forward biased. In this way a substantially linear channel resistance characteristic is combined with the current driven characteristic of a bipolar transistor, which minimises inaccuracies due to the offset at the input of the operational amplifier 40.

The graph of Figure 4 illustrates the variation of the voltage obtained from the output of amplifier 40 with varying gate voltage at two different oscillator current levels. The shaded region indicates the operating region of the graph if the gate voltage is coupled directly to the voltage supply and the supply is considered to vary between 7.5V and 12V, as it might if battery supplied. In this region the characteristic is approximately linear for any given current within the range shown, but the tangents of the curves do not intersect the supply voltage axis at zero, leading to an offset power error.

By connecting the gate instead to the tap of a potential divider, as shown in Figure 3, the origin of the graph can effectively be moved to the left as shown in Figure 5, although the biasing is still such

that over the permitted range of the supply, the device is operated in the enhancement mode. It will be seen that the output voltage of the amplifier 40 is now proportional to both oscillator current and supply voltage. In the circuit of Figure 3, a variable resistor 48 in the potential divider 46 allows the offset to be set if required. The feedback resistance is also presettable to allow adjustment of the gain/supply voltage ratio.

In practice, the characteristic of Figure 5 does exhibit a slight curve which can be used to advantage in tailoring the multiplier response to the actual, as opposed to estimated or predicted, output power of the unit thereby largely compensating for any inaccuracy arising from the assumption that the power dissipated in the load is proportional to the product of the supply voltage and the oscillator current (due to variations in efficiency of the oscillator over the supply voltage range).

The FET 44 is selected for low gate current, i.e. high transconductance, and type no. BF 256 C has been found suitable.

Referring again to Figure 3, the signal from the multiplier 34 is low-pass filtered by the resistor 50 and the capacitor 52 and fed to another operational amplifier 54, this amplifer being connected as a comparator, having one input coupled to an adjustable voltage reference generated by variable resistance 56 connected across a 1.225 V zener diode 57.

The output of the comparator can be seen to be equivalent to the oscillator requirement in that its output is high when the oscillator is required to be "on" to increase power.

Yet a further operational amplifier 58, connected as another comparator, in normal operation inverts the "power error" signal from the first comparator 54 and drives a switching transistor 60 coupled via resistor 62 and capacitor 63 to the gate of the MOSFET 10.

The rate of change of the "power error" signal is determined by the slew rate of the amplifier 54 (typically 0.5 V per microsecond) and the time constant for the low pass filter formed by capacitor 52 and resistor 50 (typically 10 nanofarads and 180 kilohm respectively). A combination of the rate of change of the power error signal and the threshold voltages, dictated by the hysteresis loop of amplifier 58, determine the modulation frequency.

Switching the oscillator off is merely accomplished by stealing the MOSFET gate drive by making switching transistor 60 conductive. Starting the oscillator again, however, requires a transient "kick", which is generated by the inductor 64 in the collector circuit of the transistor 60.

When the unit drives a high resistance load, the alternating voltage generated across the resonant circuit 14 can be sufficient that the feedback voltage applied via capacitor 24 to the gate of the MOSFET 10 can exceed the maximum permitted gate voltage of the device. This possibility is avoided by clamping the gate to a maximum voltage (+20V) determined by a zener diode 65 coupled to the positive supply. To maintain an average gate voltage of one half of the supply voltage(for 50% mark-space switching) a second zener diode 66 clamps the gate to a minimum voltage of -5V (The gate switching threshold is approximately 8V). The clamping arrangement has the advantage that excess feedback energy is fed back to the supply, reducing energy loss.

The unit incorporates means for shutting down the oscillator when the supply voltage decreases beyond a set lower level, in this case 7.5V. Comparator 58 uses as its reference voltage the output of the 1.225V zener diode 58 which is applied to the non-inverting input. The other input, in the absence of a low "power error" signal from comparator 54, is at a voltage determined by the supply voltage and the potentiometer 68, and the latter is arranged to generate a d.c. level of 1.225V when the supply voltage is 7.5 V. Thus, when the voltage decreases below 7.5 V, the oscillator is turned off via switching transistor 60. The resistor 70 provides the hysteresis referred to earlier. This has the effect of allowing the oscillator to be restarted when a battery supply recovers after a prolonged period of operation causing the supply voltage to fall below 7.5V.

A circuit for warning of a power output below that selected is provided by another operational amplifier 72. A continuous high output from comparator 54 indicates that, as a result of reduced battery output, the oscillator is being required to run continuously. Under such circumstances the selected power output cannot be guaranteed. This condition causes a light emitting diode 74 to be energised by the amplifier 72, which acts as a monostable.

The output of amplifier 58 may remain high under two possible conditions; load mismatch and low battery power. This allows an indication of battery condition to be provided. Under particular mismatch loads the output will fail to reach the selected power level, particularly at the maximum power setting of the potentiometer 56. The maximum power available will, in these conditions, be particularly dependent on supply voltage. A convenient load mismatch is infinite impedance on an open circuit output. The power setting control may also be graduated with battery condition bands so that, with the unit activated under zero load, the control may be adjusted to find the point at which the battery condition light emitting diode 74 operates. Battery condition is then read from the scale.

Claims

1. A diathermy unit comprising oscillator means for generating an oscillatory radio frequency output signal, the oscillator means having at least one diathermy output terminal (22) for electrical connection to an electrical load in the form of living tissue, the oscillator means further having means for causing the radio frequency of the oscillating output signal to vary automatically in response to the resistance of the living tissue load while the unit is in use, and including components (14, 18, 20) for forming a resonant output circuit, the said components including a step-up transformer (14) and, coupled in series between the said transformer and the at least one output terminal (22), a capacitor (20) which causes the resonant frequency of the resonant output circuit to vary with the said load resistance.

2. A diathermy unit according to claim 1, characterised by a self-tuning oscillator, the said components (14, 18, 20) being arranged such that the variable resonant frequency resonant circuit comprises, when the unit is coupled to the load, the combination of the said components and the load, and such that the resonant circuit determines the operating frequency of the oscillator.

3. A diathermy unit according to claim 2, characterised in that the said components comprise the parallel combination of a further capacitor (18) and said step-up transformer (14A, 14B), which parallel combination is coupled to the said series-coupled capacitor (20) such that the parallel combination and the series-coupled capacitor (20) are coupled together in series between a pair of output terminals (22) of the unit.

4. A diathermy unit according to claim 3, characterised by being arranged such that a decrease in load resistance brings about a decrease in resonant frequency.

5. A diathermy unit according to claim 2, characterised in that the oscillator is a power oscillator forming the output stage of the unit.

6. A diathermy unit according to claim 5, characterised in that the oscillator includes a power MOSFET (10) coupled to the resonant circuit.

7. A diathermy unit according to claim 6, characterised in that the source of the MOSFET (10) is connected to an oscillator ground.

8. A diathermy unit according to claim 6 or claim 7, characterised in that the drain of the MOSFET (10) is coupled to a power supply line of the unit via a primary winding (14A) of the transformer (14).

9. A diathermy unit according to claim 4, characterised in that the inductance constitutes or forms part of the step-up transformer (14).

10. A diathermy unit according to claim 1, characterised in that the oscillator means includes an oscillator device (10) arranged such that it develops an output across a primary winding (14A) of the step-up transformer (14), and a pair of output terminals (22) for coupling to the load (12) in the form of living tissue, the transformer (14) having the series-connection of the primary winding and a secondary winding (14B) coupled to the output terminals (22).

11. A diathermy unit according to claim 10, characterised in that the transformer (14) is an auto-transformer.

12. A diathermy unit according to claim 10 or claim 11, characterised in that the resonant circuit includes a further capacitor (18) coupled in parallel with an inductance (14A, 14B) formed by the step-up transformer (14), the said series-coupled capacitor (20) being coupled in series between the resulting parallel combination and one of the output terminals (22).

13. A diathermy unit according to claim 5, claim 6, or any of claims 10 to 13, characterised by diode clamping means (65) for limiting oscillator feedback.

14. A diathermy unit according to claim 13, characterised in that the clamping means comprises a zener diode (65) coupled between an input connection (26) of the oscillator device (10) and a power supply for the oscillator.

15. A diathermy unit according to any preceding claim, characterised by an oscillator feedback circuit comprising a series feedback capacitor (24) coupled to a clamping arrangement (65, 66).

16. A diathermy unit according to any preceding claim, characterised by means (64) for providing a transient "kick" signal for starting the oscillator means.

17. A diathermy unit according to any preceding claim, characterised by means (32, 34, 38, 44, 58, 60) for controlling the power output of the unit in response to a feedback signal.

18. A diathermy unit according to claim 17, characterised in that the means for controlling the power output includes means (32) for measuring the current consumed by an output stage of the unit.

19. A diathermy unit according to any preceding claim, characterised in that it is arranged such that the output signal is pulse width modulated by a pulsed modulation signal of variable mark-to-space ratio.

20. A diathermy unit according to any of claims 1 to 16, characterised by including an analogue multiplier (34) arranged to receive signals representative of the voltage and current respectively of the said output signal, comparison means (38) coupled to receive a product signal from the analogue multiplier (34) for comparing the product signal with a reference signal, and means for varying the power of the said output signal in response to the product signal thereby to regulate the output power of the unit to a predetermined level.

21. A diathermy unit according to claim 20, characterised in that the analogue multiplier comprises an amplifier (40) having a resistance governing the gain of the amplifier, wherein the resistance comprises a field-effect transistor (44) arranged to have its gate forward biased, the multiplier having a first input coupled to the gate of the field-effect transistor (44) and a second input formed by or coupled to an input of the amplifier (40).

22. A diathermy unit according to claim 21, characterised in that the amplifier (40) is a differential amplifier having an inverting input and a non-inverting input, a first resistance coupled between the inverting input and a ground or a.c. ground point, and a second resistance coupled between the inverting input and an output of the amplifier (40), wherein the field-effect transistor (44) forms at least part of either the first or the second resistance, and wherein the non-inverting input forms or is coupled to the second input of the amplifier (40).

23. A diathermy unit according to claim 21 or 22, wherein the field-effect transistor (44) is a depletion type field-effect transistor arranged to be biased into the enhancement region of its characteristic.

24. A diathermy unit according to any of claims 21 to 23, characterised by including a shunt resistance (32) coupled to pass a current representative of the output signal current, the first input of the multiplier (34) being connected to receive a voltage related to the voltage of the output signal and the second input of the amplifier (40) being connected to one end of the shunt resistance (32).

25. A diathermy unit according to claim 1, characterised in that the said at least one output terminal (22) is coupled to a resonant output network having the combination of an inductance (14) and a capacitor (18) connected in parallel.

26. A diathermy unit according to any preceding claim, characterised by being battery-powered.

Patentansprüche

1. Diathermiegerät mit einer Oszillatoreinrichtung zum Erzeugen eines oszillierenden Hochfrequenz-Ausgangssignals, wobei die Oszillatoreinrichtung mindestens einen Diathermie-Ausgangs-Anschluß (22) für die elektrische Verbindung mit einer elektrischen Last in Form von lebendem Gewebe aufweist, und die Oszillatoreinrichtung weiterhin eine Einrichtung aufweist, die bewirkt, daß die Hochfrequenz des oszillierenden Ausgangssignals in Reaktion auf den Widerstand der Last des lebenden Gewebes automatisch variert, während das Gerät in Betrieb ist, und Komponenten (14, 18, 20) beinhaltet zum Bilden eines Ausgangs-Resonanzkreises, wobei die Komponenten einen Aufwärtstransformator (14) und einen zwischen den Transformator und den mindestens einen Ausgangs-Anschluß (22) in Serie geschalteten Kondensator (20) beinhalten, der bewirkt, daß die Resonanzfrequenz des Ausgangs-Resonanzkreises mit dem Lastwiderstand variert.

2. Diathermiegerät nach Anspruch 1, gekennzeichnet durch einen selbst abstimmenden Oszillator, wobei die Komponenten (14, 18, 20) so ausgebildet sind, daß, wenn das Gerät mit der Last gekoppelt ist, der Resonanzkreis mit variabler Resonanzfrequenz die Kombination der Komponenten und der Last umfaßt, und so daß der Resonanzkreis die Betriebsfrequenz des Oszillators bestimmt.

3. Diathermiegerät nach Anspruch 2, dadurch gekennzeichnet, daß die Komponenten eine parallele Kombination eines weiteren Kondensators (18) und des Aufwärtstransformators (14A, 14B) aufweisen, wobei die parallele Kombination mit dem in Serie geschalteten Kondensator (20) so gekoppelt ist, daß die parallele Kombination und der in Serie geschaltete Kondensator (20) zusammen in Serie geschaltet sind zwischen einem Paar von Ausgangsanschlüssen (22) des Geräts.

4. Diathermiegerät nach Anspruch 3, dadurch gezeichnet, daß es so ausgebildet ist, daß eine Abnahme im Widerstand der Last eine Abnahme der Hochfrequenz bewirkt.

5. Diathermiegerät nach Anspruch 2, dadurch gekennzeichnet, daß der Oszillator ein Leistungsoszillator ist, der die Ausgangsstufe des Geräts bildet.

6. Diathermiegerät nach Anspruch 5, dadurch gekennzeichnet, daß der Oszillator einen Leistungs-MOSFET (10) beinhaltet, der mit dem Resonanzkreis gekoppelt ist.

7. Diathermiegerät nach Anspruch 6, dadurch gekennzeichnet, daß der Source-Anschluß des MOSFET (10) mit einer Oszillatormasse verbunden ist.

8. Diathermiegerät nach Anspruch 6 oder 7, dadurch gekennzeichnet, daß der Drain-Anschluß des MOSFET (10) mit der Energieversorgungsleitung des Geräts über eine Primärwicklung (14A) des Transformators (14) gekoppelt ist.

9. Diathermiegerät nach Anspruch 4, dadurch gekennzeichnet, daß die Induktivität den Aufwärtstransformator (14) bildet oder einen Teil davon.

10. Diathermiegerät nach Anspruch 1, dadurch gekennzeichnet, daß die Oszillatoreinrichtung eine Oszillatorvorrichtung (10), die so ausgebildet ist, daß sie ein Ausgangssignal über einer Primärwicklung (14A) des Aufwärtstransformators (14) entwickelt, und ein Paar von Ausgangsanschlüssen (22) zum Koppeln zu der Last (12) in Form von lebendem Gewebe beinhaltet, wobei die Serienschaltung der Primärwicklung und einer Sekundärwicklung (14B) des Transformators (14) mit den Ausgangsanschlüssen (22) gekoppelt ist.

11. Diathermiegerät nach Anspruch 10, dadurch gekennzeichnet, daß der Transformator (14) ein Auto-Transformator ist.

12. Diathermiegerät nach Anspruch 10 oder 11, dadurch gekennzeichnet, daß der Resonanzkreis einen weiteren Kondensator (18) beinhaltet, der parallel mit einer Induktivität (14A, 14B) gekoppelt ist, die durch den Aufwärtstransformator (14) gebildet wird, wobei der in Serie geschaltete Kondensator (20) zwischen der entstehenden Parallelkombination und einem der Ausgangsanschlüsse (22) in Serie geschaltet ist.

13. Diathermiegerät nach Anspruch 5, 6 oder einem der Ansprüche 10 bis 13, gekennzeichnet durch eine Diodenklemmvorrichtung (65) zum Begrenzen der Rückkopplung des Oszillators.

14. Diathermiegerät nach Anspruch 13, dadurch gekennzeichnet, daß die Klemmvorrichtung eine Zener-Diode (65) umfaßt, die zwischen eine Eingangsverbindung (26) der Oszillatorvorrichtung (10) und eine Stromversorgung für den Oszillator geschaltet ist.

15. Diathermiegerät nach einem der vorhergehenden Ansprüche, gekennzeichnet durch einen Oszillator-Rückkopplungsschaltkreis, der einen seriellen Rückkopplungskondensator (24) beinhaltet, der mit einer Klemmanordnung (65, 66) gekoppelt ist.

16. Diathermiegerät nach einem der vorhergehenden Ansprüche, gekennzeichnet durch eine Einrichtung (64) zum Liefern eines transienten "Kick"-Signals zum Starten der Oszillatoreinrichtung.

17. Diathermiegerät nach einem der vorhergehenden Ansprüche, gekennzeichnet durch eine Einrichtung (32, 34, 38, 44, 58, 60) zum Steuern der Leistungsabgabe des Geräts in Reaktion auf ein Rückkopplungssignal.

18. Diathermiegerät nach Anspruch 17, dadurch gekennzeichnet, daß die Einrichtung zum Steuern der Leistungsabgabe eine Einrichtung (32) zum Messen des Stroms, der durch eine Ausgangsstufe des Geräts verbraucht wird, beinhaltet.

19. Diathermiegerät nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß es so ausgebildet ist, daß das Ausgangssignal durch ein pulsierendes Modulationssignal mit variablem Zeichen/Pause-Verhältnis impuls-

breitenmoduliert wird.

20. Diathermiegrät nach einem der Ansprüche 1 bis 16, dadurch gekennzeichnet, daß es einen analogen Multiplizierer (34), der so ausgebildet ist, daß er Signale empfängt, die jeweils die Spannung bzw. den Strom des Ausgangssignals darstellen, eine Vergleichseinrichtung (38), die so geschaltet ist, daß sie ein Produktsignal von dem analogen Multiplizierer (34) empfängt zum Vergleichen des Produktsignals mit einem Referenzsignal, und eine Einrichtung zum Variieren der Leistung des Ausgangssignals in Reaktion auf das Produktsignal, um dadurch die Ausgangsleistung des Geräts auf ein vorbestimmtes Niveau zu regulieren, aufweist.

21. Diathermiegerät nach Anspruch 20, dadurch gekennzeichnet, daß der analoge Multiplizierer einen Verstärker (40) umfaßt, der einen Widerstand, der die Verstärkung des Verstärkers regelt, hat, wobei der Widerstand einen Feldeffekt-Transistor (44) aufweist, der so ausgebildet ist, daß sein Gate vorwärts vorgespannt ist, wobei ein erster Eingang des Multiplizierers mit dem Gate des Feldeffekt-Transistors (44) gekoppelt ist, und ein zweiter Eingang durch einen Eingang des Verstärkers (40) gebildet ist oder mit diesem gekoppelt ist.

22. Diathermiegerät nach Anspruch 21, dadurch gekennzeichnet, daß der Verstärker (40) ein Differenzverstärker ist mit einem invertierenden Eingang und einem nicht-invertierenden Eingang, einem ersten Widerstand, der zwischen dem invertierenden Eingang und einem Massepunkt oder Wechselstrom-Massepunkt gekoppelt ist, und einem zweiten Widerstand, der zwischen den invertierenden Eingang und einen Ausgang des Verstärkers (40) gekoppelt ist, wobei der Feldeffekt-Transistor (44) zumindest einen Teil von entweder dem ersten oder dem zweiten Widerstand bildet und wobei der nicht-invertierende Eingang den zweiten Eingang des Verstärkers (40) bildet oder mit ihm gekoppelt ist.

23. Diathermiegerät nach Anspruch 21 oder 22, wobei der Feldeffekt-Transistor (44) ein Feld-Effekt-Transistor vom Verarmungstyp ist, der so angeordnet ist, daß er in den Anreicherungsbereich seiner Charakteristik vorgespannt wird.

24. Diathermiegerät nach einem der Ansprüche 21 bis 23, dadurch gekennzeichnet, daß ein Nebenschlußwiderstand (32) vorhanden ist, der so geschaltet ist, daß er einen Strom durchläßt, der für den Ausgangssignalstrom repräsentativ ist, wobei der erste Eingang des Multiplizierers (34) so geschaltet ist, daß er eine Spannung empfängt, die mit der Spannung des Ausgangssignals in Bezug steht, und der Zweite Eingang des Verstärkers (40) mit einem Ende des Nebenschlußwiderstands (32) verbunden ist.

25. Diathermiegerät nach Anspruch 1, dadurch gekennzeichnet, daß der mindestens eine Ausgangsanschluß (22) mit einem resonanten Ausgangsnetzwerk gekoppelt ist, das die Kombination einer Induktivität (14) und eines Kondensators (18), die parallel geschaltet sind, aufweist.

26. Diathermiegerät nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß es batteriebetrieben ist.

Revendications

1. Appareil de diathermie comprenant des moyens d'oscillateur pour générer un signal de sortie oscillant à fréquence radio, les moyens d'oscillateur comportant au moins une borne de sortie de diathermie (22) pour le branchement électrique à une charge électrique se présentant sous la forme d'un tissu vivant, les moyens d'oscillateur comportant en outre des moyens pour faire varier automatiquement la fréquence radio du signal de sortie oscillant en réponse à la résistance de la charge de tissu vivant pendant que l'appareil est en cours d'utilisation, et comprenant des composants (14, 18, 20) pour former un circuit de sortie résonnant, ces composants comprenant un transformateur élévateur (14) et, branché en série entre le transformateur et la borne de sortie au moins unique (22), un condensateur (20) qui fait varier la fréquence de résonance du circuit de sortie résonnant avec la résistance de la charge.

2. Appareil de diathermie selon la revendication 1, caractérisé par un oscillateur à accord automatique, les composants (14, 18, 20) étant disposés de façon que le circuit résonnant à fréquence de résonance variable comprenne la combinaison de ces composants avec la charge lorsque l'appareil est couplé à la charge, et de façon que le circuit résonnant détermine la fréquence de fonctionnement de l'oscillateur.

3. Appareil de diathermie selon la revendication 2, caractérisé en ce que les composants comprennent la combinaison parallèle d'un autre

condensateur (18) avec le transformateur élévateur (14A, 14B), cette combinaison parallèle étant couplée au condensateur branché en série (20) de façon que la combinaison parallèle et le condensateur branché en série (20) soient branchés ensemble en série entre une paire de bornes de sortie (22) de l'appareil.

4. Appareil de diathermie selon la revendication 3, caractérisé en ce qu'il est disposé de façon qu'une diminution de la résistance de la charge produise une diminution de la fréquence de résonance.

5. Appareil de diathermie selon la revendication 2, caractérisé en ce que l'oscillateur est un oscillateur de puissance formant l'étage de sortie de l'appareil.

6. Appareil de diathermie selon la revendication 5, caractérisé en ce que l'oscillateur comprend un MOSFET de puissance (10) couplé au circuit résonant.

7. Appareil de diathermie selon la revendication 6, caractérisé en ce que la source du MOSFET (10) est branchée à la masse de l'oscillateur.

8. Appareil de diathermie selon la revendication 6 ou la revendication 7, caractérisé en ce que le drain du MOSFET (10) est branché à une ligne d'alimentation de puissance de l'appareil par l'intermédiaire de l'enroulement primaire (14A) du transformateur (14).

9. Appareil de diathermie selon la revendication 4, caractérisé en ce que l'inductance constitue ou fait partie du transformateur élévateur (14).

10. Appareil de diathermie selon la revendication 1, caractérisé en ce que les moyens d'oscillateur comprennent un dispositif d'oscillateur (10) disposé de manière à développer un signal de sortie aux bornes de l'enroulement primaire (14A) du transformateur élévateur (14), et une paire de bornes de sortie (22) pour le branchement à la charge (12) se présentant sous la forme du tissu vivant, le transformateur (14) comportant le branchement série de l'enroulement primaire et d'un enroulement secondaire (14B), couplé aux bornes de sortie (22).

11. Appareil de diathermie selon la revendication 10, caractérisé en ce que le transformateur (14) est un autotransformateur.

12. Appareil de diathermie selon la revendication 10 ou la revendication 11, caractérisé en ce que le circuit résonnant comprend un autre condensateur (18) branché en parallèle avec une inductance (14A, 14B) formée par le transformateur élévateur (14), le condensateur branché en série (20) étant branché en série entre la combinaison parallèle résultante et l'une des bornes de sortie (22).

13. Appareil de diathermie selon la revendication 5, la revendication 6, ou l'une quelconque des revendications 10 à 13, caractérisé par des moyens de blocage à diode (65) pour limiter la rétroaction de l'oscillateur.

14. Appareil de diathermie selon la revendication 13, caractérisé en ce que les moyens de blocage comprennent une diode zener (65) couplée entre un branchement d'entrée (26) du dispositif d'oscillateur (10) et une alimentation de puissance de l'oscillateur.

15. Appareil de diathermie selon l'une quelconque des revendications précédentes, caractérisé par un circuit de rétroaction d'oscillateur comprenant un condensateur de rétroaction série (24) couplé à un dispositif de blocage (65, 66).

16. Appareil de diathermie selon l'une quelconque des revendications précédentes, caractérisé par des moyens (64) pour fournir un signal de"réaction" transitoire destiné à faire démarrer les moyens d'oscillateur.

17. Appareil de diathermie selon l'une quelconque des revendications précédentes, caractérisé par des moyens (32, 34, 38, 44, 58, 60) pour commander la puissance de sortié de l'appareil en réponse à un signal de rétroaction.

18. Appareil de diathermie selon la revendication 17, caractérisé en ce que les moyens de commande de la puissance de sortie comprennent des moyens (32) destinés à mesurer le courant consommé par l'étage de sortie de l'appareil.

19. Appareil de diathermie selon l'une quelconque des revendications précédentes, caractérisé en ce qu'il est disposé de façon que le signal de sortie soit modulé en largeur d'impulsion par un signal de modulation pulsé de rapport marquage-espacement variable.

20. Appareil de diathermie selon l'une quelconque des revendications 1 à 16, caractérisé en ce qu'il comprend un multiplicateur analogique (34) disposé pour recevoir des signaux représentant respectivement la tension et le courant

du signal de sortie, des moyens de comparaison (38) couplés pour recevoir un signal de produit du multiplicateur analogique (34) afin de comparer le signal de produit à un signal de référence, et des moyens pour faire varier la puissance du signal de sortie en réponse au signal de produit, de manière à réguler ainsi la puissance de sortie de l'appareil à un niveau prédéterminé.

21. Appareil de diathermie selon la revendication 20, caractérisé en ce que le multiplicateur analogique comprend un amplificateur (40) muni d'une résistance commandant le gain de l'amplificateur, cette résistance étant constituée par un transistor à effet de champ (44) monté de façon que sa grille est polarisée positivement, le multiplicateur comportant une première entrée couplée à la grille du transistor à effet de champ (44), et une seconde entrée formée par une entrée de l'amplificateur (40) ou couplée à celle-ci.

22. Appareil de diathermie selon la revendication 21, caractérisé en ce que l'amplificateur (40) est un amplificateur différentiel comportant une entrée inverseuse et une entrée non-inverseuse, une première résistance branchée entre l'entrée inverseuse et la masse ou un point de masse en courant alternatif, et une seconde résistance branchée entre l'entrée inverseuse et une sortie de l'amplificateur (40), le transistor à effet de champ (44) formant au moins une partie, soit de la première résistance, soit de la seconde résistance, et l'entrée noninverseuse formant la seconde entrée de l'amplificateur (40) ou étant couplée à celle-ci.

23. Appareil de diathermie selon la revendication 21 ou 22, caractérisé en ce que le transistor à effet de champ (44) est un transistor à effet de champ de type à déplétion monté pour être polarisé dans la zone d'augmentation de sa caractéristique.

24. Appareil de diathermie selon l'une quelconque des revendications 21 à 23, caractérisé en ce qu'il comprend une résistance de dérivation (32) branchée pour laisser passer un courant représentatif du courant du signal de sortie, la première entrée du multiplicateur (34) étant branchée pour recevoir une tension liée à la tension du signal de sortie, et la seconde entrée de l'amplificateur (40) étant branchée à une extrémité de la résistance de dérivation (32).

25. Appareil de diathermie selon la revendication 1, caractérisé en ce que la borne de sortie au moins unique (22) est branchée à un réseau de sortie résonnant comportant la combinaison d'une inductance (14) et d'un condensateur (18) branchés en parallèle.

26. Appareil de diathermie selon l'une quelconque des revendications précédentes, caractérisé en ce qu'il est alimenté par batterie.

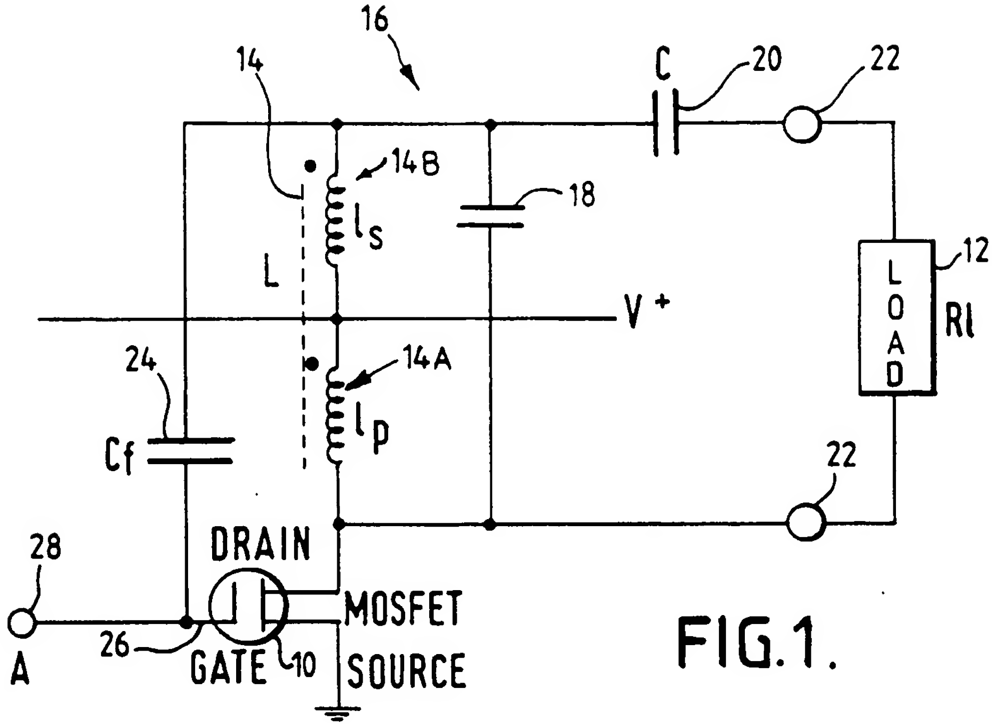
16
14
14B
l_s
18
C
20
22
L
V +
12
LOAD
Rl
24
14A
l_p
Cf
22
28
DRAIN
MOSFET
26
GATE
10
SOURCE
A

FIG.1.

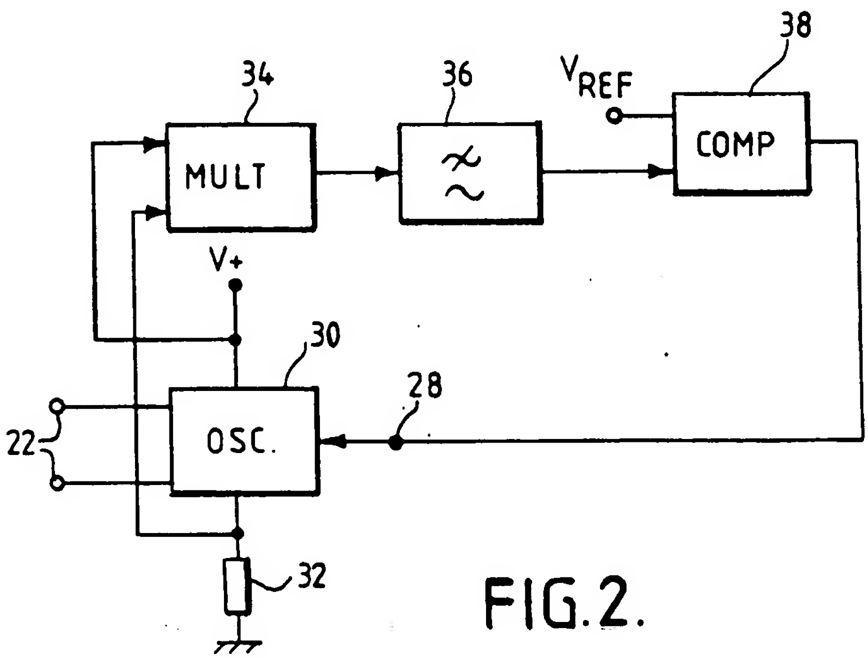
38
34
36
V_{REF}
COMP
MULT
V+
30
28
22
OSC.
32

FIG.2.

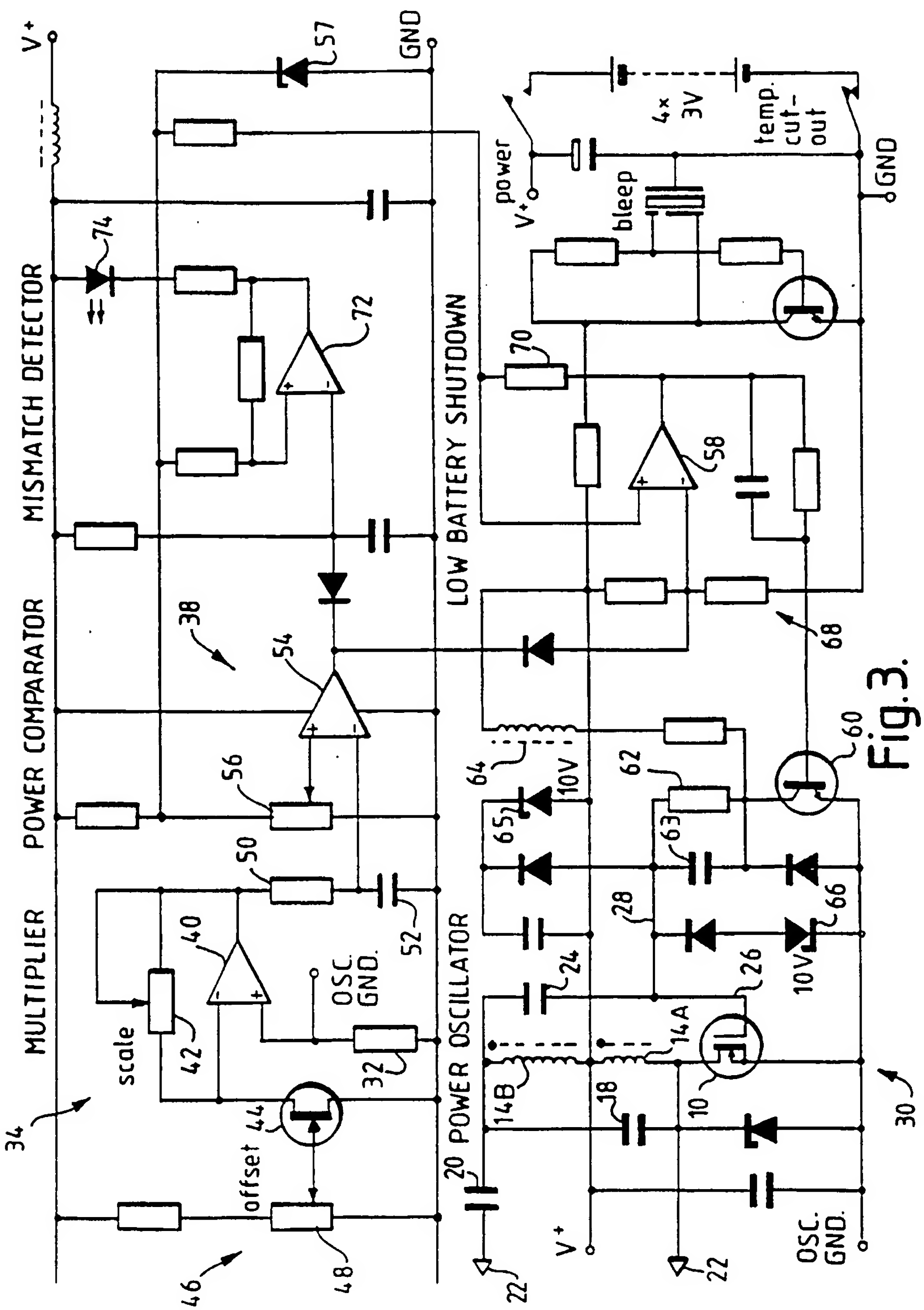
MULTIPLIER
POWER COMPARATOR
MISMATCH DETECTOR
LOW BATTERY SHUTDOWN
POWER OSCILLATOR
V+
GND
scale
offset
OSC. GND.
power V+
bleep
4x 3V
temp. cut-out
10V
34
46
48
44
42
40
32
50
52
56
54
38
57
74
72
70
58
68
60
62
63
64
65
66
28
26
24
20
22
18
10
14A
14B
30

Fig.3.

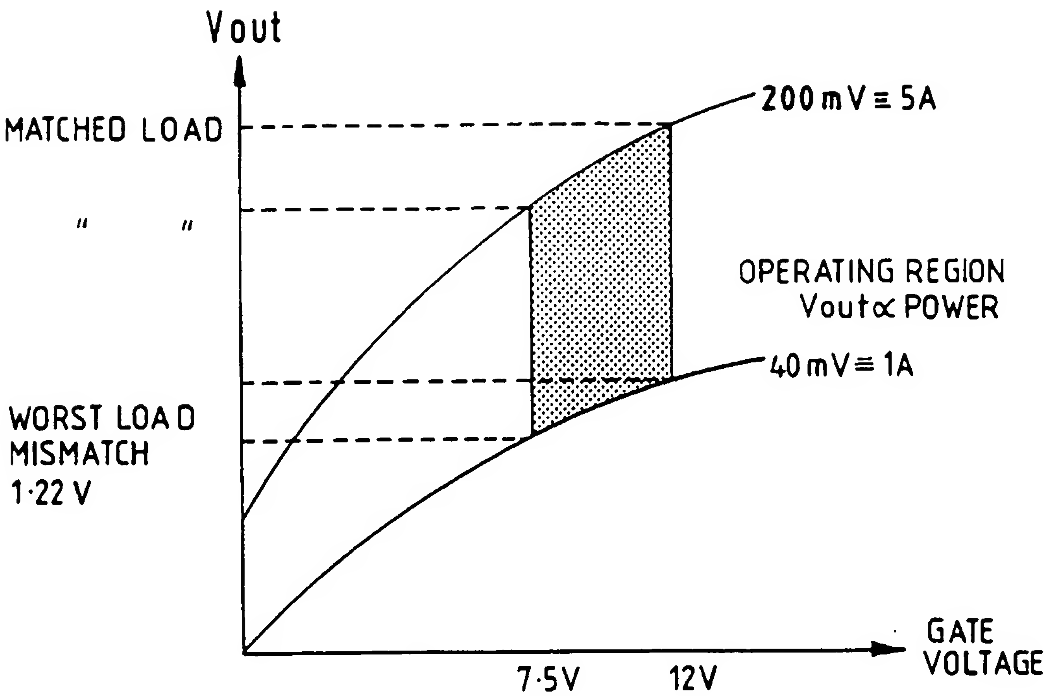
Vout
MATCHED LOAD
" "
WORST LOAD
MISMATCH
1·22 V
200 mV ≡ 5A
OPERATING REGION
Vout ∝ POWER
40 mV ≡ 1A
GATE
VOLTAGE
7·5V
12V

Fig.4.

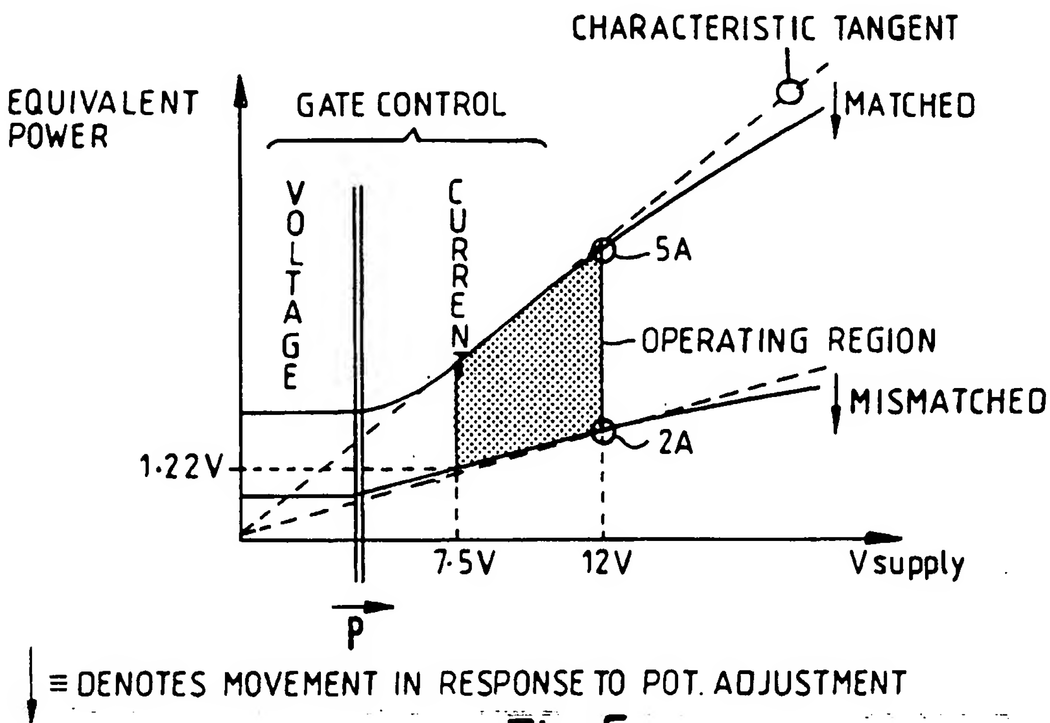
CHARACTERISTIC TANGENT
EQUIVALENT
POWER
GATE CONTROL
VOLTAGE
CURRENT
MATCHED
5A
OPERATING REGION
MISMATCHED
2A
1·22V
7·5V
12V
Vsupply
P
≡ DENOTES MOVEMENT IN RESPONSE TO POT. ADJUSTMENT

Fig.5.